

PROJECT FACT SHEET

CONTRACT TITLE: Advanced Seismic Geodiagnostics-Borehole Acoustic Source/ Instrumentation for Fracture Mapping

ID NUMBER: FEW A053

B&R CODE: AC1005000

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PROJECT SITE

CITY: Los Alamos

STATE: NM

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CONTRACT PERFORMANCE PERIOD:

03/01/1988 to 04/15/2001

PROGRAM: Supporting Research

RESEARCH AREA: Rsvr Characterization

PRODUCT LINE: ADIS

FUNDING (1000'S)	DOE	CONTRACTOR	TOTAL
PRIOR FISCAL YRS	1499	0	1499
FISCAL YR 2000	250	0	250
FUTURE FUNDS	250	0	250
TOTAL EST'D FUNDS	1999	0	1999

OBJECTIVE: To advance the state-of-the-art in borehole seismic imaging of reservoir fractures through the development of new downhole measurement capabilities and new analytical methods for processing and interpretation of microseismic events.

PROJECT DESCRIPTION:

Background: The National Petroleum Council and various industrial organizations have identified the need for improved capabilities for gathering and integrating seismic data used to understand the nature and performance of oil and gas reservoirs and to improve the efficiency of reservoir exploitation. These needs include greater depth-of-penetration in borehole measurements, higher resolution seismic images derived from data acquired on the earth's surface, and the ability to gather these data in oil field environments at lower costs. Los Alamos National Laboratory has been at the forefront of borehole microseismic reservoir monitoring technology, a powerful technique for mapping conductive reservoir fractures at distances of hundreds of meters from boreholes. In addition, we have been developing new borehole receivers for deployment in production wells and very small diameter boreholes or borehole annuli in an effort to demonstrate lower-cost applications of borehole seismic imaging techniques.

Work to be Performed: Under a separate program, Los Alamos is investigating the feasibility of drilling micro-boreholes (~1 inch), a capability that opens up the possibility of directly measuring subsurface reservoir properties and delineating reservoir boundaries at much lower cost and more systematically than is possible using current technologies limited to commercial exploration and development wells. Realization of the benefits of micro-drilling will require miniaturization of conventional logging tools as well as developing new instruments for fluid detection and monitoring reservoir processes. In addition, we have been developing new borehole receivers for deployment in production tubing (2-3/8-in and greater) and very small diameter boreholes or borehole annuli, in an effort to demonstrate lower-cost applications of borehole seismic imaging techniques. Here we propose to extend these efforts to continue the development of imaging techniques making use of these borehole tools and to extend the capability for long-term, low cost monitoring of producing reservoirs. In FY00, work will include development and refinement of automated techniques used to improve the resolution of reservoir structures and flow paths imaged from induced microseismic data sets.

PROJECT STATUS:

Current Work: We will continue the work initiated under the Cotton Valley Imaging Consortia. With a ten-fold improvement in location precision, the master-event technique (see below) results in remarkable resolution of discrete fracture geometry. Implementation of the technique, however, is usually laborious and impractical for large data sets. Recently, we modified a statistical collapsing technique to be implemented as an additional constraint in a joint-hypocenter determination (JHD) inversion scheme. Comparison of automated JHD- collapsing and the manually implemented master-event mapping results for a common data set was favorable. For FY00 we propose to further improve the automated JHD- collapsing technique. This promises to be a powerful and efficient tool for gleaning highly detailed images of reservoir fracture geometry from microseismic data sets.

Currently, the collapsing constraint added to the JHD scheme is to shift event locations (hypocenters) towards the center of mass of the events within a sphere of some radius. The indiscriminate association of a particular event within an arbitrary sphere of hypocenters and the center-of-mass bias will tend to result in an over-shifting of locations, and, hence, a reduction and distortion of resolved fracture dimensions. The method could be improved by a priori association of events to sub-cluster geometry that already exist in the raw, uncollapsed event locations. Further development and extension of the JHD collapse technique will include: 1) development and application of statistical techniques to define sub-clusters of hypocenters following initial JHD mapping; 2) determination of sub-cluster geometry, as lines, planes or volumes, based on fitting ellipsoids to sub-clusters (principal component analysis); and 3) apply JHD collapse with bias to collapse toward the a priori determined cluster geometry. An alternative to (1) would be a graphical interface that would enable a user to easily identify and group sub-clusters. The algorithm will be tested on synthetic data sets and other microseismic data sets for direct comparison with applications of other collapsing techniques. The latter applications will include analysis of the entire Cotton Valley data sets.

Scheduled Milestones:

Task 1. Initial master event location work for Cotton Valley Data (test cases)	06/00
Task 2. Develop techniques for sub-cluster hypocenter identification and geometry	09/00
Task 3. Modification of JHD collapse to a priori cluster geometry and comparison with Task 1	12/00

Accomplishments: In 1997 Los Alamos participated in an hydraulic fracturing experiment sponsored by Union Pacific Resources and the Cotton Valley Fracture Imaging Consortia (Chevron, Pennzoil, Texaco, Halliburton, BJ Services, ARCO, and Protechnics). This consortia of oil producer and service companies conducted an extensive fracture imaging experiment in the Cotton Valley gas field, east Texas. Hydraulic fracturing is routinely used at Cotton Valley and other similar tight-gas-sand reservoirs to enhance production. Not known, or poorly understood,

aspects of the fracturing process are: 1) the orientation, height and lateral extent of the process zones of individual treatments; 2) what the best infield drilling strategy may be, based on treatment results; and 3) whether or not hydraulic fractures are or can be contained within productive sand intervals. The Consortia drilled and completed two monitor wells with 2350-ft length, 48-level, 3-component geophone arrays cemented outside of 2-7/8 inch production tubing. Los Alamos deployed their two-level, 1-11/16 inch diameter geophone tool within the open production tubing of one of the monitor wells. Analysis to date includes: 1) evaluation of various decimated array geometries and quantifying the data quality required to effectively map as signal-to-noise degrades; 2) development of effective velocity calibration techniques to assure the best absolute location accuracy; 3) comparison of receiver performance and noise levels for cemented versus retrievable, borehole-locking receivers; 4) completed the mapping and error analysis of the Cotton Valley data set, a total of 2475 events; and 5) determination of high-precision locations via a master-event location scheme for an entire treatment. The master-event locations reveal a reduction in fracture zone width from about 30 to 10 m or less, and fine scale intra-layer containment, details that could not be seen from the original set of locations. Systematic examination of waveforms along the fracture length indicate highly similar signals varying only gradually with position, thereby implying a uniform focal mechanism throughout the stimulated volume. A composite focal mechanism indicates left-lateral strike-slip is the predominant failure mechanism throughout. Fine-scale temporal growth patterns reveal the dynamics of the fracturing process.

Project publications:

Rutledge, J. T., W. S. Phillips, and B. K. Schuessler, "Reservoir characterization using oil-production induced microseismicity, Clinton County, Kentucky," *Tectonophysics*, 289, 129-152, (1998).

Phillips, W. S., J. T. Rutledge, T. D. Fairbanks, T. L. Gardner, M. E. Miller, and B. S. Maher, "Reservoir fracture mapping using microearthquakes: Two oilfield case studies," *SPE Reservoir Evaluation & Engineering*, 114-121, April, (1998).

Phillips, W. S., T. D. Fairbanks, J. T. Rutledge, and D. W. Anderson, "Induced microearthquake patterns and oil-producing fracture systems in the Austin Chalk," *Tectonophysics*, 289, 153-169 (1998).

Rutledge, J. T., W. S. Phillips, L. S. House, R. J. Zinno, "Microseismic mapping of a Cotton Valley hydraulic fracture using decimated downhole arrays," 68th Ann. Mtg., Soc. of Explore. Geophys., 338-341, (1998).

Walker Jr., R. N., R. J. Zinno, J. B. Gibson, T. Urbancic, and J. Rutledge, "Carthage Cotton Valley Fracture Imaging Project - Image methodology and implications," *SPE Paper 49194*, 73rd Society of Petroleum Engineers Annual Technical Conference and Exhibition, (1998).

Urbancic, T.I., Shumila, V., Rutledge, J.T., and Zinno, R.J., Determining hydraulic fracture behavior using microseismicity, *Proceedings of the 37th U.S. Rock Mechanics Symposium*, 991-997, Vail, Colorado, U.S.A., June 6-9, 1999.

Project patent:

Engelke, R.P., R.O. Hedges, A.B. Kammerman, and J.N. Albright, Compact chemical energy system for seismic applications. United States Patent Number: 5,789,697